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Letter to the Editor

Current Densities and Total Contact Currents During Forest Clearing Tasks Under 400 kV Power Lines

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The aim of the study was to analyze all values of electric currents from measured periods while performing tasks in forest clearing. The objective was also to choose and analyze measurement cases, where current measurements successfully lasted the entire work period (about 30 min). Two forestry workers volunteered to perform four forest clearing tasks under 400 kV power lines. The sampling frequency of the current measurements was 1 sample/s. The maximum values of the current densities were 1.0–1.2 mA/m^2 (calculated internal EFs 5.0–12.0 mV/m), and the average values were 0.2–0.4 mA/m^2. The highest contact current was 167.4 μA. All measured values during forest clearing tasks were lower than basic restrictions (0.1 V/m and 0.8 V/m) of the International Commission on Non-Ionizing Radiation Protection. Bioelectromagnetics.37:423–428, 2016.

Key words: current density; total contact current; power line; forest clearing; forestry workers

INTRODUCTION

According to Fingrid [2016], handling of trees near power lines in Finland includes, for example, (i) felling of high trees so that they do not cause harm (clearing of power line rights-of-way); (ii) felling of yard trees near power lines; and (iii) handling of border zone trees. The operational safety of the power line is ensured by clearing the power line rights-of-way mechanically at intervals of 5–8 years (average every 6 years), which means that about 6,000 ha are cleared every year. The clearing is carried out mechanically (using machines or a clearing saw) [Fingrid, 2016].

The focus of the study was to analyze the average values of measurement data (contact currents and currents in the head) and how they varied during forest clearing tasks under 400 kV power lines. In an earlier article [Korpinen et al., 2009], we only described the maximum total contact currents, maximum currents in the head, and maximum current densities in the neck at 400 kV substations and power lines. For the task "Cutting vegetation under power lines," the maximum total contact current was 15.6 μA and the maximum current density in the neck was 1.5 mA/m^2. The "Cutting vegetation under power lines" is a much different task than other tasks (which we have studied), because workers use a saw and are also very close to vegetation. Vegetation and sawing can have an influence on electric field (EF) exposure. Therefore, we studied and analyzed the forest clearing task under 400 kV power lines.

Occupational exposure to EFs can be compared to guidelines of the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and Directive 2013/35/EU of the European Parliament and Council [ICNIRP, 2010; European Parliament and Council, 2013]. According to ICNIRP guidelines, basic restrictions are the following: internal

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EFs (50 Hz) for occupational exposure are 0.1 V/m to central nervous system (CNS) tissue of the head, and 0.8 V/m to all head and body tissues [ICNIRP, 2010]. According to Directive 2013/35/EU of the European Parliament and Council on minimum health and safety requirements regarding exposure of workers to risks arising from physical agents (EFs) at 50 Hz, action levels (ALs, workers) of the directive regarding EFs are as follows: low ALs 10 kV/m (rms) and high ALs 20 kV/m (rms) [European Parliament and Council, 2013]. The health effects exposure limit value (ELV), which is related to electric stimulation of all peripheral and CNS tissues in the body, is 1.1 V/m (peak) to 50 Hz, and the sensory effects ELV, which is related to EF effects on the CNS in the head, is 0.14 V/m (peak) [European Parliament and Council, 2013].

We chose only forest clearing tasks because during these tasks, workers are typically in possession of a forestry clearing saw. In the worst possible clearing case, when a worker cuts down a tree, the current that can be conducted through the tree can flow first to the clearing saw, then to the body, then to the ground. This can happen when the tree is just coming down as the contact of the treetop to the stump is lost.

The aim of our new article was to analyze all values of electric currents from measured periods while performing forest clearing tasks. The objective was also to choose and evaluate from the measurement data cases where the current measurements successfully lasted the entire work period (about 30 min).

Fig. 1. Photo of forest clearing task (A) in place I (first measurement day).

MATERIALS AND METHODS

Two workers volunteered to perform four forestry clearing tasks (A–D) together under 400 kV power lines during three summer days. The workers' neck circumferences were 0.38 m and 0.40 m, respectively. There was no special medical check, but the workers themselves felt that they were fit to work. All work tasks were conducted with informed consent and the approval of the local ethics committee (Pirkanmaa Health District, Finland, decision R05041). The work periods lasted about 30 min (1 sample/s). Figure 1 shows the work sites. In place I (Fig. 1), the trees were spread out, whereas in place II (Fig. 2), the

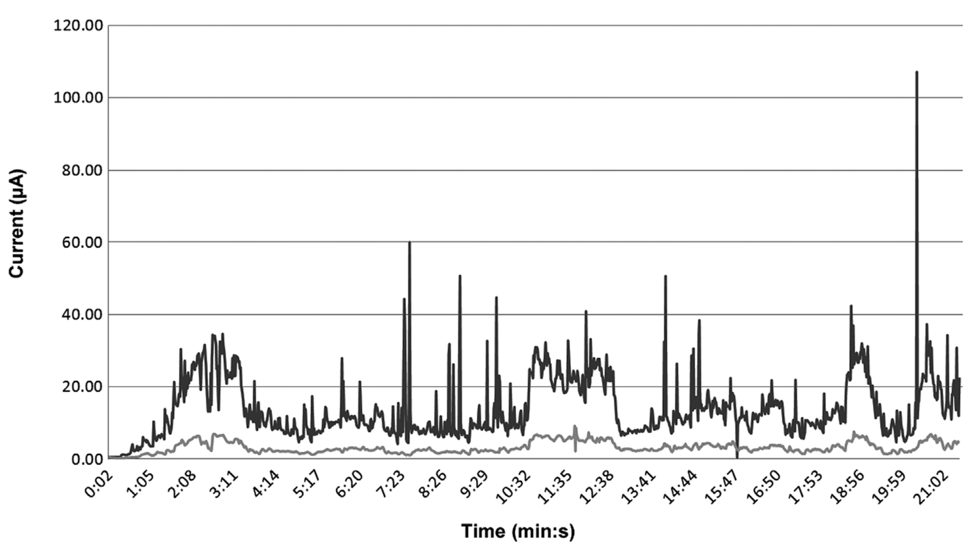

Fig. 2. Measured currents in the head and total contact currents during forest clearing task A.

trees were close together. One task (A) was performed in place I and the others (B–D) in place II. We completed measurement tasks C and D on the same day. During the experiments, the power lines were energized. Safety was evaluated before measurements.

The workers' head currents and total contact currents were measured by the previously published helmet-mask system [Korpinen et al., 2009]. In the helmet-mask system, the contact current is the current flowing between the worker and a conducting object when an otherwise isolated worker touches a grounded object or when a grounded worker touches an otherwise isolated object. During forest clearing tasks, the measurement system was a little different than for other tasks. We used boot electrodes because workers needed to walk while fulfilling their duties. We measured the contact current (amperes, A) by fastening an electrode to the arm and by connecting that electrode to the ground via a Unitest Hexagon 520 multimeter (Beha, Glottertal, Germany). Fortum Service also added a low-pass filter to the measurement system because the spark plug's electric spark in the clearing saw disturbed measurements. In the data, there were extra disturbance peaks. The low-pass filter was used in tasks B–D. Furthermore, we tested different clearing saws to find the best measurement data. In task A, the saw was a Husqvarna forest clearing saw (Stockholm, Sweden), which workers typically use. In tasks B–D, workers used a Partner forest clearing saw (Husqvarna, Stockholm, Sweden). The sampling frequency of the multimeter was 1 sample/s. After each measurement, data were transferred to a laptop. In forestry clearing tasks, the calibration coefficient of the measurement system was 1.26 because we used the helmet without the mask, and the EF was vertical.

We also measured EFs under the power lines (in places I and II). We chose an area without large trees or bushes (a reference place), for example, a dirt road, and there we performed EF measurements with a three-axis commercial EFA-3 meter (Wandel and Coltermann, Eningen U.A., France; accuracy 5%, RMS). Measurement height was 1 m.

Average current density in the neck was calculated from current in the head and circumference of the neck. In this calculation, cross-section of the neck was approximated by a circle. The internal EF was calculated by dividing current density by average conductivity of tissues (0.1–0.2 S/m) [Dawson and Stuchly, 1998].

Table 1 shows results (maximum, average, standard deviation [SD]) from current measurements during forest clearing tasks under 400 kV power lines and internal EFs calculated from current densities. Averages of currents or current densities were calculated from all measured work periods.

Maximum values of current density in the neck and internal EF in the neck were as follows from all cases of tasks: task (A) 1.0 mA/m^2 and 5.0–10.0 mV/m; task (B) 1.2 mA/m^2 and 6.0–12.0 mV/m; task (C) 1.0 mA/m^2 and 5.0–10.0 mV/m; and task (D) 1.1 mA/m^2, and 5.5–11.0 mV/m. The measured EF was 2.2–2.3 kV/m in the reference place of place I when temperature was 25–30 °C and relative humidity was 40–58%. The EF was 4.1 kV/m in the reference place of place II (second measurement day) when temperature was 19–20 °C and relative humidity was 68–70%. In third measurement day (place II), EFs were 4.5–4.6 kV/m when relative humidity was 56–60% and temperature 16–17 °C. Figures 2–5 show the measured currents in the head and total contact currents during forest clearing tasks.

TABLE 1. Measured Maximum and Average Currents in Head, Measured Maximum and Average Values of Total Contact Currents, Calculated Average Current Densities in Neck, and Calculated Maximum Internal EF at Tasks A–D Under 400 kV Power Lines

	Current in head				Total contact current				Current density in neck			Internal electric field
Task	n	Max (μA)	Ave (μA)	SD (μA)	n	Max (μA)	Ave (μA)	SD (μA)	Max (mA/m^2)	Ave (mA/m^2)	SD (mA/m^2)	Max (mV/m)
A	1272	9.2	3.2	1.6	1271	107.1	13.7	8.4	1.0	0.4	0.2	5.0–10.0
B	1804	12.4	3.3	2.5	1804	167.4	18.9	17.6	1.2	0.3	0.3	6.0–12.0
C	1890	9.7	2.5	1.9	1890	49.9	12.2	9.3	1.0	0.2	0.2	5.0–10.0
D	1849	11.0	2.0	1.4	1849	110.8	11.7	11.3	1.1	0.2	0.1	5.5–11.0

A: Forest clearing task in place I (first measurement day). B: Forest clearing task in place II using filter (second measurement day). C: Forest clearing task in place II using filter (third measurement day). D: Forest clearing task in place II using filter (third measurement day).

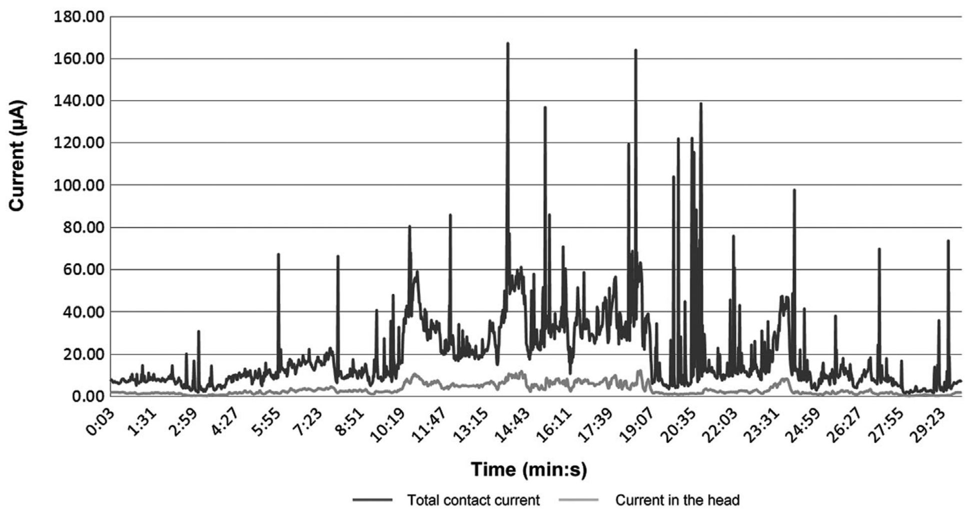

Fig. 3. Measured currents in the head and total contact currents during forest clearing task B.

DISCUSSION AND CONCLUSIONS

When we compared our measurements during forest clearing tasks to other tasks, which we have studied, we encountered some new difficulties. The chainsaw influenced measured data, and we had technical problems. Moreover, the chainsaw and trees influenced workers' exposure situations. Then, we had some difficulties with grounding cables. The workers moved quickly, and cables were often broken under workers' boots. It was also sometimes difficult to find a suitable ground connection under power lines. For example, in task B, we implanted four steel rods in the ground to ensure that our measurement system worked correctly.

In our results, maximum values of current density in the neck were very similar, about 1 mA/m^2 in all measurement tasks. It was not possible to find differences between place I (spread out trees) and place II (clustered trees). However, it is possible that the amount of trees influenced exposure of EFs, but it was difficult to verify with our measurements during forest clearing tasks. It was difficult to obtain the same EF results with measurements and calculations. Our measurement results of forest clearing tasks were lower than our earlier results of some tasks at 400 kV

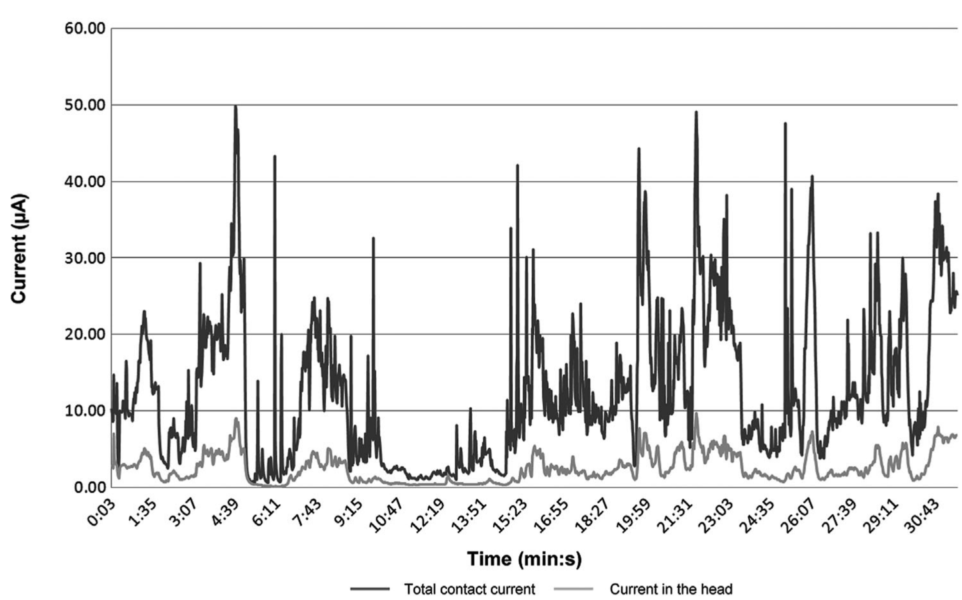

Fig. 4. Measured currents in the head and total contact currents during forest clearing task C.

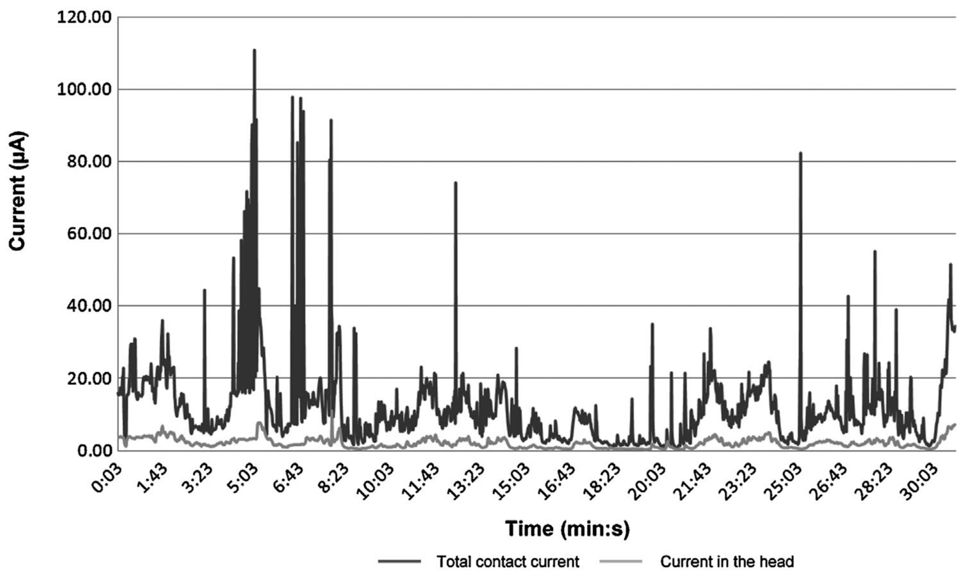

Fig. 5. Measured currents in the head and total contact currents during forest clearing task D.

substations [Korpinen et al., 2009]; however, we conducted only four measurements (only two places), which lasted successfully during the entire work period (about 30 min). Although these tasks are quite typical in Finland, we only used two different chainsaws. Hence, it is possible to utilize our results as a reference point for analyzing similar tasks in Finland.

Moreover, two forestry workers volunteering to perform four forest clearing tasks do not provide enough data for statistical analysis. However we have more than 1200 values (sample/s) of all separate measurements. Therefore, we could calculate average and SD of separate measurements A, B, C, or D.

Total contact current in task B is higher than in other tasks (both mean value and maximum value). The reason for the difference can be the measurement area. Under the left phase of the power line there was a high rocky hillock on which trees were significantly less dense than the rest. In this case, a single tree was induced by a higher current, such as in task B. In addition, EF was also a little higher there than in other parts of the clearance area.

In conclusion, it can be stated that all measured values during forest clearing tasks were lower than various basic restrictions found in ICNIRP, [2010] guidelines, which recommend an internal EF strength of 0.1 V/m (CNS) and 0.8 V/m (peripheral nervous system) [ICNIRP, 2010]. Contact currents were also lower than 1 mA (ICNIRP reference value). However, the number of measurements is so limited that it is not possible to make a good conclusion. Repeating measurements are good to do in the future.

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REFERENCES

Dawson TW, Stuchly MA. 1998. High-resolution organ dosimetry for human exposure to low-frequency magnetic fields. IEEE Trans Magn 34:708–718.

European Parliament and Council. 2013. Directive 2013/35/EU of the European Parliament and Council of 26 June 2013 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields) (20th individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC) and repealing Directive 2004/40/EC. Official Journal of the European Union L 179, 29/6/2013. Available from: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:179:0001:0021:EN:PDF [Accessed 26 July 2014].

Fingrid. 2016. Handling of border zone trees. Available from: http://www.fingrid.fi/en/grid_projects/maintenance/Handling%20of%20border%20zone%20trees/Pages/default.aspx [Accessed 21 February 2016].

ICNIRP (International Commission on Non-ionizing Radiation Protection). 2010. Guidelines for limiting exposure to time-varying electric and magnetic fields (1 Hz to 100 kHz). Health Phys 99:818–836.

Korpinen LH, Elovaara JA, Kuisti HA. 2009. Evaluation of current densities and total contact currents in occupational exposure at 400 kV substations and power lines. Bioelectromagnetics 30:231–240.

SUPPORTING INFORMATION

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